THE EFFECT OF GROUND OYSTER MUSHROOM (*Pleurotus sajor- caju*) IN THE NUTRITIONAL ENHANCEMENT, PHYSICOCHEMICAL PROPERTIES AND STRUCTURAL CHANGES OF HERBAL SEASONING

by

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Globally, human of different ethnicities have known mushroom for long time ago. The mushrooms have been used as normal diet since they are recognized as a delicacy and possess unique taste and odour (Mattila *et al.*, 2000). Mushrooms are grouped in the Fungi Kingdom. In the past, they were categorized as plants. Mushrooms belong to the class of *Basidiomycetes* and order *Agaricales.* They do not have the ability to synthesize foods like green plants and these special types of edible fungi forming flesh umbrella like fruiting bodies (Bahl, 1998). Mushrooms are different in sizes, colours, textures and structures that favour their spore formation. The cap is known as cuticle and normally varies among different mushroom species and texture is sticky or slimy. The stalk is the stem-like structure on which the cap is mounted and the length is varies depending on the species (Gyar and Ogbonna, 2006).

Previously, mushroom is also called 'white vegetables' or 'boneless vegetarian meat'. They are appreciated and accepted by all peoples including vegetarians as well as non-vegetarians (Agrahar-Murugkar and Subbulakshmi, 2005). Mushrooms contain of high protein content and vitamins and minerals, phenolic compounds and ribonuclease, soluble and insoluble fiber, glucans and chitin (Manzi *et al.,* 2004; Mattila *et al.,* 2002; Ngai and Ng, 2004; Silva *et al*., 2002). Since many years ago, the early herbalists were more interested in the medicinal compounds of the mushrooms rather than basic value as a source of food. Moreover,

mushrooms are nutritious food comparable to vegetables. Besides, mushrooms have been valued as an edible and medical resource, easy to cultivate and widely consumed all over the world. About 45% of mushrooms produced are consumed in the fresh form while the other 55% are normally processed (5% in dehydrated form and 50% in canned form) since their shelf-life in the fresh form is very short (Singh *et al*., 2010).

The subtle and unique flavour of mushrooms have been attracted the fruiting bodies of mushrooms to be used as food and food ingredients for centuries. Recently, they also have become more attractive as a source of bioactive components to be applied in functional foods (Tseng *et al*., 2008). Moreover, nutritional properties of mushrooms have been investigated by many researchers (Chang and Miles 1992; Crisan and Sands 1978; Reis *et al.,* 2012; Rupak and Arun, 2015). Currently, the health benefits of mushroom have stimulating a lot of interest particularly in its consumption as food as well as in the cure of diseases (Chang, 1980). Mushrooms also valued as valuable components of organic nutrients such as digestible proteins, fiber, antioxidants, vitamins and minerals (Nnorom, 2012; Pereira *et al.,* 2012; Xiaofei *et al.,* 2011). Mushrooms also possess some prominent therapeutic characteristics such as antimicrobial, exert immune-stimulatory effects, lowering blood cholesterol, anticancer and also antioxidant (Barros *et al*., 2007a; Silveira *et al*., 2015). They accumulated various compounds of secondary metabolites such as phenolics, polyketides, terpenes and steroids (Turkoglu *et al*., 2007).

The consumption of food and beverages rich in polyphenols can reduce the risk of cardiovascular diseases (CVD), stroke and certain types of cancer. In conjunction, many epidemiological studies confirmed the association between antioxidant properties and polyphenol in mushrooms (Barros *et al*., 2007b; Jagadish

et al., 2009). The fruiting bodies of this fungus have gained much attraction when they are found in nature in terms of the structure and colours. In fact, mushrooms have been used in the treatment and prevention of many diseases such as bronchitis, gastritis, cancer as well as in health and longevity maintenance.

Typical consumer expectations for the new processed food products or existing products are tastiness, satisfying, healthful, convenient and inexpensive. Interestingly, mushrooms are being investigated for their role as pharma-nutritional foods. In China, the nutraceutical products and dietary supplements based on mushroom extracts are frequently used, along with different combinations of other herbal preparations (Barros *et al*., 2008; Carbonero *et al*., 2006). On the other hand, the presence of polar phenolic compounds naturally exists in herbs and spices have been attributed to their antioxidant activity (Wu *et al.,* 2004).

Mushrooms are already known as one of the easiest loss in quality due to their quick perishable products after harvesting. In average, the good condition of mushroom is about one to three days if they are stored at room temperature. Many factors affect the changes in quality and physical characteristics of mushrooms. Moreover, this situation becomes a big problem to the distribution and marketing chain of the fresh product. The deterioration of cap opening, stipe elongation, weight loss and other post-harvest changes such as browning, lack of physical protection and high respiration rate are the main components that contribute to the short shelf life of mushrooms (Akram and Kwon, 2010; Singh *et al*., 2010; Sommer *et al* , 2010). Mushroom generally consists of approximately 90% water. Due to the most perishable nature of mushrooms, processing is needed to extend the shelf life for off-season commercial use (Devece *et al.,* 1999). Preservation technique applied to the mushrooms is determined by several factors such as types of the processed product

and the targeted storage time. Drying are used instead of freezing and canning for the long time preservation of mushrooms. On the other hand, oyster mushroom also has been encapsulated to maintain their active ingredient in the products (Fang and Bhandari, 2010).

Recently, the issues regarding the human nutrition are always being important and the outbreak of food related to animal meat sources has becomes the issues to be more complicated. The increase in human population globally necessitates a need for exploration of the other source of proteins. Therefore, continuous investigation of naturally ingredients or substances becomes a good reason for nutritional substitute to the existing foods. Recently, many foods introduced contain mushrooms as the main ingredients. The trend offers value added benefits based on the existing products and also invention to the new products (Pereira *et al.,* 2012).

Nowadays, convenience foods offer the concept such as Ready to Cook (RTC) and Ready to Eat (RTE) food which food can be consumed immediately after thermal treatment. Therefore, customers only need minimal preparation of the food (Sloan, 2005). Furthermore, the demand for RTE food is steadily increasing, thus understanding to the mechanisms related to processing, nutritional and consumption of convenience food is an important matter. Incorporation of ground oyster mushroom with herbal ingredients gives new good combination to diversify the application of herbs and mushroom in RTE food products. Previous study was successfully done in substituting white flours with oyster mushroom powder in bakery products, soups, sauces, instant noodle, meat-based products, pasta and flour mixes. Recently, it was discovered that oyster mushroom powder has improved some nutrients content of butter biscuit (Wan Rosli *et al.,* 2012) and rice-based products (Aishah and Wan Rosli, 2013).

In recent time, family eating patterns, variety of food choices and higher educational level have affected the existing traditional family structures. Moreover, many families are facing almost similar problems related to limited of time for food preparation. More interesting if both Ready to eat (RTE) and ready to use (RTU) food products would become more convenient and useful to consumers if they had a longer storage period. Furthermore, the main characteristics that present consumers need are convenience as well as quality in their food products. These key elements will continue to the survival of food products for many years to come.

Moreover, convenience foods are usually associated to negative side effects related to health such as high in sugar, fat and calorie content which responsible for obesity, high blood pressure and consequently reduce quality of life (Szabo, 2011). However, high demand for nutritive foods by health conscious consumers has led to the development of nutritious food that should be regarded as a bonus to the consumers. Convenience products are considered less likely to cause foodborne illness because during cooking preparation, adequate heat treatment has been applied which can eliminate and reduce the microbial load in the products (Waters, 2000). Typically, herbal seasoning (HS) is lacking in protein content and high in fat and carbohydrate content. Thus, the addition of mushrooms is interesting since it rich in crude fibre and protein content. They are also contains low fat, low calories and essential vitamins and possess multi-functional medicinal properties (Manzi *et al.*, 2001). However, in Malaysian Food Regulation 1985 and Food Act 1981, Regulation 395 (Foods not standardized elsewhere) has stated that food in form of paste is not permitted to include preservatives in the formulation. Thereby, the proper techniques must be applied to preserve the food to be shelf stable at ambient temperature. In addition, development of new product or re-formulation of existing product gives the

new dimension for healthier product to consumer. In that context, food developer can produce food with low sugar, salt, fat and calorie to consumers (Lupton *et al*., 2010; Roodenburg *et al.,* 2011).

The information regarding nutritional value of mushrooms in bottle packaging is generally limited compared to canning. Bottling technniques are useful since the products can be hot filling which is extremely important to reach a high level of food safety and to limit the contamination in filling room in ensuring a safe filling technology. On the other hand, the technique can extend the shelf stability of the products (Berk, 2013; Bottani *et al.,* 2011). There is also limited information on nutritional composition and antioxidant properties of mushrooms after addition into RTE-based food products. Many studies only focused on postharvest handling and cultivation of mushrooms. Yet, very few studies in Malaysia focused on RTE food in bottle packaging. Hence, the aim of the present study is to produce herbal seasoning (HS) added with oyster mushroom and to determine the nutritional value and the anti-oxidative properties of the finished RTE products.

1.2 Objectives

The objectives of this study are:

1.2.1 General objectives

To investigate the nutritional composition, antioxidant properties and sensory acceptance of herbal seasoning (HS) products formulated with ground *Pleurotus sajor-caju.*

1.2.2 Specific objectives

1. To formulate herbal seasoning paste added with ground oyster mushroom.
2. To determine the nutritional value, physico-chemical and antioxidant properties in the herbal seasoning paste added with ground oyster mushroom.
3. To study the morphological changes in herbal seasoning paste added with ground oyster mushroom.
4. To determine the acceptability of the herbal seasoning paste added with ground oyster mushroom.

CHAPTER 2

LITERATURE REVIEW

2.1 Mushroom

Mushrooms are classified as a group of higher fungi, which belong to the class *Basidiomycetes* and the order *Agaricales*. Generally, the sporocarp (fruity body) and mycelium are the main parts of this fungus. The mycelium or hypae is the treelike structure hidden in the soil which mycelium absorbs food nutrients, whereas hypae form the fruit (sporocarp) structure on the surface of substrate that suitable for growth especially when humidity is favourable. Spore producing tissue in mushroom is called hymenium (Etang *et al*., 2006). The difference in structure, size, colour and texture make mushrooms suitable for spore formation. The stickiness of cap and slimy in texture is called the cuticle and varies among different mushroom species.

Cultivation of an edible mushroom has gained popularity and more important because of the nutritional value they exert since past decade. At the same time, mushroom cultivation has also generated an opportunity for self-employment of large number of people. In general, throughout the world, more than 3000 of mushrooms refer as prime edible species with 100 of them are cultivated commercially. From the most cultivated species, 10 of them were cultivated on industrial scales (Chang and Miles, 2004). Those species are recognized as commercial scales and their cultivation becomes importance as a promising agro-based land independent enterprise.

Statistically, the data on mushroom intake are sparse. Since 40 years ago, retail *per capita* availability of mushrooms has shown more than tripled from only

0.9 pounds/person in 1970 to 3.1 pounds/person in 2010 (USDA, 2013).The annual world production of mushroom has crossed over 5 million metric tons and within 10 years is forecasted to reach 7 million metric tons (Kumar *et al*., 2011). In the meantime, 100 countries have been actively practiced mushroom farming all over the world.

China is still the biggest producer with the production has across 1.5 million metric tons in 2007 and is expected to continuously increases over the time (Aida *et al*., 2009). High volume of production and staggering in the global economic value in conjunction with their nutritional value (Kalac, 2009) and their medicinal properties (Ferreira *et al*., 2009; Ferreira *et al.,* 2010) are the main reason for the increasing in mushroom consumptions.

Many edible mushrooms species are found in nature. But, generally only 20 species have been applied in food while 10 species of them are cultivated significantly in big scales. These edible fungi have gained popularity or attention because of their high in dietary fiber content, high in protein and a valuable source of non-starchy carbohydrates. They also low in fat, contain minerals and essential amino acids (Agrahar-Murugkar and Subbulakshmi, 2005; Ghorai *et al*., 2009). In addition, they provide significant amount of vitamins (B1, B2, B12, C, D and E) (Heleno *et al.,* 2010). The dietary fiber of the mushrooms such as chitin and β-glucan is associated to therapeutic properties. They significantly related to prevention of cancer, heart disease, viral infection, cholesterol levels and hypertension (Bobek and Galbavy, 1999; Manzi and Pizzoferrato, 2000). On the other hand, there are many researches whose focus their study to treat diseases using bioactive compounds from mushrooms such as proteo-glucans, polysaccharides, phenol compounds and

nucleotides. Some studies have proven the significant results in the treatment of the cancer, high cholesterol, immune system improvement and anti-angiogenic activity.

Overall, both of edible and medicinal mushrooms are the main dominated properties of mushrooms produced in the world. The dry weight basis of mushroom fruiting bodies about 50 % - 65 % represents the carbohydrate content of mushrooms (Wani *et al*., 2010). Basically, the distinctive texture, special aroma, flavour and high in nutritional properties are the main reason for the consumption of these edible mushrooms worldwide.

In general, mushrooms are appreciated widely in nutritional properties throughout the world. It is because the nutritious food they possess and found in good quantity depending on species (Fukushima, 2000; Kalac, 2009; Mallavadhani *et al*., 2006). They also edible to be consumed either in fresh or cooked form. Furthermore, mushrooms are regarded as healthy raw materials and ideal for people with hypertension and high blood pressure. The unsaturated fatty acid (oleic and linoleic acid), high amount of fiber with moderate value of energy shows the good properties of mushrooms (Manzi *et al.*, 1999).

On the other aspect, the nutritional value, good flavour as well as distinctive texture are the main contributors to the acceptance of these edible mushrooms worldwide (Diyabalanage *et al.,* 2008). For instance, the application of various mushroom species in culinary around the world are related to their good flavour, taste and nutritious potential.

2.2 Oyster mushroom

Pleurotus spp. which is also popular as oyster mushrooms are edible mushroom commercially cultivated throughout the world. This important edible mushroom from *Pleurotus* species are recognized edible, nutritious and rank second among the cultivated mushrooms in the world. These fungus are becomes widespread throughout the hard wood forests of the world. The *Pleurotus* species has many advantages as a cultivated mushroom such as rapid growth of mycelia and saprophytic colonization. Moreover, the techniques of cultivation are simple and inexpensive, while the different climatic conditions are favourable for several kinds of other species. Currently, *P. ostreatus, P. florida, P. eryngii, P. cystidiosis, P. flabellatus, P. cornucopie, and P. sajor-caju* are the most popular species. In addition, commercial value of *Pleurotus* species significantly increased due to their nutritional advantages (Zervakis and Balis, 1996).

In Asia and Europe countries for instance, genera of *Pleurotus sajor-caju* (PSC) is among the various edible mushroom types, widely cultivated and also in different regions of the world. The higher adaptability and bio efficiency altogether with simple techniques and low cost production technology usually farmers make millions of dollar from this single species (Jonathan *et al.*, 2008). In agricultural aspect, mushrooms are known to convert lignocellolosic residues from agricultural forests into protein rich food (Khan *et al.*, 2011; Michal *et al.*, 2011). The mushroom can easy to be cultivated on different natural substrate and agricultural waste with wide range of temperatures. The ability of oyster mushrooms to grow at a various agricultural waste residues has increased tremendously their cultivation all over the world. In addition, these wide ranges of agro based wastes are useful as decomposers

of these white-root fungi (Kurt and Buyukalaca, 2010). The structure of young bodies mushrooms contain higher moisture therefore the texture are soft and brittle, whereas the fully matured ones almost leathery, tough and most probably have lost their water content (Fasidi and Kadiri, 1993). Agro based residues which becomes the major source of lignocellulosic materials are being the solid state fermentation substrate of *Pleurotus sajo-caju* and other edible fungi. Zadrazil (1980) reported that the degradation process of wheat straw as substrate was efficient since *Pleurotus sajor-caju* has very high saprophytic colonizing ability. Presently, the most worldwide cultivated edible mushroom are button mushroom (*Agaricus bisporus),* shiitake (*Lentinus edodes,* oyster mushrooms (*Pleurotus spp)* and winter mushroom *(Flamulina velutipes)* (Reis *et al.,* 2012).

The *Pleurotus sajor-caju* commonly called as oyster mushroom, due to its oyster like shape is a widely established cultivable mushroom species. On the other aspects*, P. sajor-caju* is appreciated more than other *Pleurotus* species in aspect of delicious taste, low in fat, high in protein and rich in minerals (calcium, phosphorus, iron) and vitamins (thiamin, riboflavin and niacin) (Caglarirmak, 2007; Kurtzman, 2005; Manzi *et al*., 1999).

These species are considered popular since they have relatively simple method of cultivation and good in nutritional properties. Besides, the protein content they possess (containing all exogenous amino acids) especially B vitamins and minerals (Manzi *et al.*, 1999; Shah *et al.*, 1997). On the other hand, vegetarians prefer these species as a valuable foodstuff. In nutritional context, mushroom not containing cholesterol, but rich in protein (30% based on dry weight), contain B vitamins and have lovastatin about 2.8% by dry weight (cholesterol lowering molecule). Besides, they can act as biological response modifier due to their

excellent sources of polysaccharides as therapeutic molecules. Therefore, the popularity also has increased since they contain good nutritional value and easy to cultivate (Gonzaga *et al.*, 2005). Mushrooms are regarded popular among vegetarians and non vegetarian since they are similar to vegetables. The low titratable acid and low pH content (6.1 - 7.2) are the other factors suggested why mushroom can be consumed safely. On the other side, mushrooms are good sources of phytosterols (Mattila *et al.*, 2002).

Presently, mushrooms are attractive and become functional food and a source for new drug development. This fungus has also been applied in the preparation of therapeutic teas since many years ago in Oriental regions. Therefore, *Pleurotus sajor-caju* is popular species and successfully cultivated around the world and considered to be delicious (Zhang *et al.,* 2002). Besides of the nutritional and medicinal properties, they are most appreciated for the good texture and special flavour (Mallavadhani *et al.,* 2006; Manzi and Pizzoferrato, 2000; Manzi *et al.,* 2004; Smiderle *et al.,* 2006).

The cultivation of mushrooms especially *P. sajor-caju* is high profitable agribusiness. Mushrooms could become important additional items to farmers as they have excellent flavour and good taste. Therefore, farmers can value add the existing products or create a new dimension of promising products and practical way to improve their socio-economic income while fully utilizing other crops by-products or co-products.

In Malaysia, the genus *pleurotus* normally known as oyster mushrooms are the most widely edible fungal food cultivated in the country. Oyster mushroom is usually being used in the preparation of soup and also be fried with other vegetables

or spices. They are also popular in countries such as India, China and Japan due to the discovery of its valuable nutritive and medicinal values. Presently, the species of *Pleurotus sajor-caju* is dominated in cultivation in most all countries. They are very low in fat and carbohydrate, while possess good quality protein and vitamins. By consuming this edible fungi which has low fat content and high soluble fiber content is claimed to reduce the cholesterol level in blood (Pramanik *et al.*, 2007) and prevent hyperlipidemia content (Schneider *et al.*, 2011). Mushroom as food has also been acknowledged to ameliorate the protein malnutrition facing by certain countries which more depending upon cereals (Dehariya *et al.,* 2010; Pandey, 2010).

2.3 Nutritional and pharmacological benefits of mushroom

Since ancient time ago, mushrooms are becoming a famous food in daily meal because of their nutritious and medicinal values. Apart from flavour and taste, the fruiting bodies of mushrooms are rich in organic nutrients such as excellent source of dietary fiber, digestible protein, antioxidants and high amount of minerals and vitamins (Barros *et al.*, 2007a; Cheung, 1996; Manjunathan and kaviyarasan, 2011; Mattila *et al.*, 2002; Nnorom *et al.*, 2012; Ouzouni *et al.*, 2009; Pereira *et al.,* 2012; Silveira *et al.,* 2014). The content of protein in mushroom normally ranging from 20%- 40% and has reported to be better than other legumes such as soy beans, peanuts and other high protein vegetable sources (Chang and Buswell, 1996; Chang and Mshigeni, 2001). In fact, the major component of mushrooms is water constituting about 90% of the fresh weight.

Fruiting bodies of mushroom comprising about 5 to 15% of dry matter with plentiful of B1, B2, C and D2 vitamins. They are constitute low in fat content and

high amount of proteins (19–35%) (Manzi *et al*., 1999; Mattila *et al.,* 2000). A proportion of nitrogen in mushrooms is considered in the non-protein nitrogen form. Bauer-Petrovska (2001) found that, on average, the fruiting body of mushroom contained 33% of total nitrogen. The protein content in mushroom is ranging from 34% to 89% which depend on mushroom species, while they contain very little lipid but large amount of fiber. The higher proportion of polyunsaturated fatty acid (PUFA) about 72 to 85% depend on total fat content due to the linoleic acid (Chang and Mshigeni, 2001). Furthermore, the aqueous extract contain excellent amount of vitamin B1, B2 and C which then can be consider in cholesterol reduction in blood. The present characteristics exhibited by mushroom can be considered as important tonic for health (Sadler, 2003).

Presently, food becomes a health threat. The latest figures from the World Health Organization show that the biggest issues facing by many sectors of society are obesity and poor nutrition. In fact, obesity is the most threatening and major public health problems. The active immediate action should be taken because millions peoples will suffer from an array of serious health disorders. Therefore, the consumption of dietary active compounds in human nutrition is useful since the investigation and the findings contribute wide implications for consumers, healthcare providers, regulators and industry (Bagchi, 2006).

Dietary fiber (DF) is referred to food components that derived from plant cell walls which are not digested by the endogenous secretions of the human digestive tract. They consist of pectic substances, hemicelluloses, plant gums and mucilages, algal polysaccharides, celluloses, and lignin. On the other hand, tannins, indigestible proteins, plant pigments, waxes, siliceous materials, and phytic acid also found in the fiber matrix. Hence, they give bulk to the fecal matter, not only from their inherent

mass, but also by their water-binding capacity. The amount of water bound can be four to six times from the dry weight of the fiber.

Many important bioactive compounds that display pharmaceutical properties have successfully been isolated from mushrooms which act as modulating the immune system, anti-aging, in longevity, having hypoglycemic activity and to inhibit tumour growth. The polysaccharides for instance, β- glucan forms a wide variety of branched or linear structure. These polysaccharides possess structural variability for various interaction and mechanisms in higher organisms (Agrahar-Murugkar and Subbulakshmi, 2005; Carbonero *et al.,* 2006). On the other aspect, medicinal properties such as triterpenes, lipids and phenols also have been characterized and identified in mushrooms (Maiti *et al.,* 2008).

Mushrooms also contain ergosterol, which is precursor to vitamin D2. The components only can be found in few plant foods. By exposing mushrooms to ultraviolet (UV) light, the amount of vitamin D2 in mushrooms can be significantly increased. Originally, ergosterol found in mushrooms about 21- 107 mg/100 g and is converted to vitamin D2 when expose to UV light. However, small amount of vitamin D2 are synthesized during growing and processing when the mushrooms are exposed to naturally occurring UV light. Interestingly, during processing the mushrooms can be exposed to UV light for 15-20 seconds in order to accelerate the process. In the meantime, the dose and length of exposure can affect the amount of D2 synthesized during the treatments (Roberts *et al.*, 2008). Mycelia are the growing parts of edible mushrooms similar to seeds of plants and they supply nutrients for the growth of mushroom fruit bodies. The commercial value of mushrooms was paid more attention due to the increasing cost of mushroom fruiting bodies which the fruiting bodies are marketed as the edible mushroom.

Nutritionally, the carbohydrate amount is commonly present as polysaccharides or glycoprotein ranging from 50% to 90%. They consist of chitin, hemicelluloses, β- and α-glucans, mannans, xylans and galactans. Generally, the structure of polysaccharides are present mostly as linear and branched glucans with different types of glycosidic linkages, such as (1,3),(1,6)-β-glucans and (1,3)-α-glucans, but some are true heteroglycans containing glucuronic acid, xylose, galactose, mannose, arabinose or ribose (Wasser, 2002). Polysaccharides responsible to the digestion process as soluble or insoluble dietary fibers and it depends on their molecular structure and conformation (Cheung and Lee, 1998; Johansson *et al.,* 2006; Manzi *et al.,* 2004; Manzi and Pizzoferrato, 2000). Moreover, higher ash content in foods is associated to their relatively higher in fiber content (Cheung, 1998). Thus, edible mushrooms could be ideal foods to consume for the purpose of prevention the risk of atherosclerosis since they have high fiber content. Moreover, these fungi can be good sources for the cancer treatment because they contain physiologically beneficial bioactive compounds (Finimundy *et al.,* 2013; Sarangi *et al.,* 2006).

Many studies have shown that the mushroom extracts containing β-glucan alter the function of the innate and adaptive immune systems, functioning as bioresponse modulators, rather than by directly killing bacteria, viruses, or cancer cells as cytocidal agents (Borchers *et al*., 2008). Prebiotic functions are exhibited by fungal polysaccharides and their products due to their partial hydrolysis. Prebiotic term has been introduced by Gibson and Roberfroid (1995) who exchanged ‘‘pro” for ‘‘pre”, which means ‘‘before” or ‘‘for”. Prebiotics have been defined as nondigestible food constituents that useful to the hosts by selectively stimulating the activity as well as the growth of selected number of bacteria in the colon. The

definition also partially displayed the same definition of dietary fiber except for digestibility process only efficient to the certain probiotic strains (Gibson and Roberfroid, 1995; Hidaka *et al*., 1986). Therefore, the application of certain prebiotics has been contribute for the activity of the bifidobacteria, which then may further facilitate by the ingestion of other substances such as inulin and fructo-oligosaccharides (Gibson *et al.,* 1995; Hidaka *et al*., 1986), transgalactosylated oligosaccharides (Rowland and Tanaka, 1993) and soybean oligosaccharides (Hayakawa *et al.,* 1990).

The polysaccharides of mushroom with anti tumour action are greatly different in the chemical composition and its configuration and also their physical properties. The activity of antitumour is displayed by extending range of glycans from homopolymers to very high complex of heteropolymers. This condition of activity can be linked to their different properties such as molecular size, branching rate and form and also solubility in water (Ooi and Liu, 1999; Wasser, 2002). The therapeutic properties related to their antimicrobial, antimitigenic, antiproliferative (Ngai and Ng 2004; Tambekar *et al*., 2006), antimutagenic (Lakshmi *et al.,* 2004) and antiviral (Yang *et al.,* 2001) offer by mushrooms make them suitable for low-carb foods.

In Europe, the consumption of mushroom pastes and creamy sauces are popular, and in many Asian region, mushroom-based snacks, cakes, teas and beverages are often consumed. Furthermore, China is popular for Jerky-like meat-flavored snacks, extruded "puffy" snacks, mushroom jellies and cakes. In Korea, mushroom wine is normally popular drink as mushroom extract in alcoholic drinks in Japan. On the other side, many patented products are mushrooms and fish paste, soy sauce with mushroom flavour and coffee with mushroom flavour. In addition, most

people are more interested to the nutritional and therapeutics properties of mushroom in comparison to their culinary appeal. Presently, some consumers afford to pay for products that give some positive health benefits to them. Therefore, products that display good in taste and have nutritional value are important consideration when appealing to health.

2.4 Preservation of mushroom

Preservation of food commodity is important criteria to ensure the effectiveness of the products throughout the year. Preservation is necessary to maintain the nutritional and biochemical compounds of mushroom. Production of mushrooms and their consumption shows highly demanding all over the world to get benefits of their nutritive and medicinal attributes and also their unique flavour and texture. At the same time, postharvest changes occur faster as their shelf-life at ambient temperature limited to 1 to 3 days, whereas 4 to 7 days at chilled temperature. The respiration rate with dehydration contributes to the high metabolic activity that possibly responsible to the deterioration in mushroom (Ares *et al*., 2007; Czapski and Szudyga, 2000).

Villaescusa and Gil (2003) stated that the deterioration phase during postharvest storage such as the colour deterioration, mainly because of the enzymatic browning that affect the soft and spongy texture of mushroom, due to cell growth and water migration which becomes the main changes associated with *Pleurotus spp*. Thus, the dehydation and discolouration are the major quality losses in mushrooms. Many studies have been conducted to solve on identifying the effective methods to be applied in the protection as well as to prolong the shelf life of mushrooms. The methods used such as physical treatments, thermal processing and chemical pretreatment (Berna´s *et al.,* 2006). Presently, researchers have focused for long

treatments by using the chemical pre- treatment (Lagnika *et al.,* 2012; Xiao *et al.,* 2011). Moreover, since a decade ago, freezing, drying and canning are being applied in the long-term preservation for fresh mushroom.

Numerous changes can occur during the preservation period of mushrooms. High count of bacteria fungus, enzymatic activities and biochemical changes mainly associated and contributed to the deterioration in mushrooms (Masson *et al.,* 2002). Mushrooms structurally are covered by thin epidermal layer that easily loss in water content (Jiang *et al.,* 2013). Browning reactions during storage are associated with protein and sugar decrease due to high activity of enzymes such as protease or polyphenol oxidase and the high moisture content of the carpoforus that are responsible for the changes in mushrooms. This deteriorative process also has been occurred in fresh mushroom attributes by enzymes such as polyphenoloxidase (PPO, monophenol, dihydroxy-L-phenylalanine) which limit the shelf life only for few days. The changes on browning effects of mushroom cells occurs are related to physical forces such as vibration, rough handling and ageing (Jiang *et al.,* 2010; Singh *et al.,* 2010). In the meantime, high in moisture content linked to the water activity of fruiting bodies that significantly affect the texture of mushrooms.

The most widely common practice and method use so far is drying process for guaranteeing long term storage. However, drying temperature are sensitive to those foods that sensitive to thermal treatment which can loss of colour, shrinkage, loss of texture and also their nutritional and functional properties (Attanasio *et al.,* 2004; Luangmalawat *et al.,* 2008). Moreover, flavour components in mushrooms has affected during drying by loss in flavour compounds due to their Maillard reaction (Garcia-Segovia *et al*., 2011). The unique low heat treatment coupled with consistence hot breeze air to dry-up oyster mushroom exerts good stability in

antioxidant and β-glucan content of mushrooms (Aishah and Wan Rosli, 2012). The most practiced method for dehydration of food is hot air drying. Many benefits using the methods in terms of reduction of packaging materials cost, storage and facilitate the transportation system due to low weight of the final products (Okos *et al.,* 1992).

Dried mushrooms are known for their hygroscopicity properties. Moisture sorption isotherms of mushrooms were determined by Sahbaz *et al.,* (1999) and Shivrare *et al.,* (2004). Reduction of moisture content to the below level required for microorganisms activity and growth are possible to prolong the shelf life of foods. The same mechanisms also applied for designing and optimizing drying process, evaluating storage stability, determining moisture changes and selecting appropriate packaging materials (Gal, 1987).

Recently, postharvest deterioration becomes a major problem with half of the world's fruit and vegetable crops are lost due to postharvest deterioration. Browning disorders in agricultural products are normally induced by dehydration, mechanical injury or wound deterioration (Whitaker and Lee, 1995). On the other hand, after harvesting process, the deterioration of mushrooms becomes faster if no immediate action or pretreatment is done (Akram and Kwon, 2010; Sommer *et al.,* 2010). This is a challenge to the distribution chain and marketing process of the fresh product. Basically for mushrooms, canning is normally been used in food processing. Other preservation techniques which can be applied are biological, chemical and physical treatments.

On the other hand, the key factor contribute to the successful of food product development is when the food commodity becomes more profitable and available in the market all the time when more extended shelf life of food at the best possible quality is obtained. Furthermore, longer shelf life can benefit the producer since they

can venture for long distance markets. The recent trend is towards the application of less severe preservation techniques that certainly contribute to the less damaging food products (Gould, 1989; Minnaar *et al.,* 1995). Therefore, many extensive researches have been conducted on finding the most possible technology reliable for mushroom preservation.

2.5 Functional food

Functional food is defined by European Commissions Concerted Action on Functional Food Science in Europe (FUFOSE) as food which showed to affect beneficially beyond the nutritional value required by the body and have one or more target functions in the body which linked either to enhance health or to reduce the risk of diseases. Functional food is the normal food pattern and not in the pill or capsule form. Basically, the diet rich in functional food must remain food and demonstrates its effect when the food is consumed (Diplock *et al*., 1999). The idea about functional food is initiated by Japan and the country already established the regulations regarding the application of functional foods (Hardy, 2000; Kwak and Jukes, 2001). Therefore, the bioactive compound and nutritive values of these fungi are valuable compared to their culinary and flavour features. Nowadays, the mushrooms possess many potential beneficial effects to human in terms of their functional food and medicinal value. Hence, food industry is projected to venture in the cultivation of these edible mushrooms (Eva Guillamón *et al.,* 2010).

Many factors contributes to the fully acceptance of functional foods that differ significantly due to the socio-economic, geographical, political as well as ethnic backgrounds. Mushroom generally has four functionalities consisting of nutritional value, tastiness properties, physiological effects and cultural

characteristics (Jimenez-Colmenero *et al.,* 2001; Mau, 2005). The various target functions of functional foods in the body are beyond the nutritional effects which also effective either to improve health and / or to reduce the risk of severe diseases (Stella, 2005). World Health Organization (WHO) reported that the most common death annually are related to lung, stomach, liver, colon and breast cancer. However, 30% of them can be prevented. In the meantime, 26 million cases of cancer are speculated to occur in 2030. Moreover, it is speculated in 2030, the death from cancer is forecasted about 12 million death worldwide (Boyle and Levin, 2008).

2.5.1 Oyster mushroom as functional food

Fresh oyster mushrooms have been used as food and food ingredients since long time ago. Recently, the use of mushroom can be divided either for food items or for medicinal purposes. The selection of the category has been clearly separated by the industry. In addition, this commercial edible mushroom is popular for the delicacy and their chemical compositions as well as easy to cultivate (Hernandez, 2003: Kalmis, 2008).

Mushrooms possess unique sensory characteristics and have been used for food flavouring materials that add to their functionality properties in foods (Mau, 2005). This *Pleurotus sajor-caju* species are seen to be among the most largely cultivated mushroom species in all the countries. This fungus can contribute to the human nutritional protein source and some essential amino acids. The natural advantages of this fungal kingdom related to their dietary supremacy comparable to the rest of vegetarian platters. Ghorai *et al.,* (2009) reported that mushrooms are capable to substitute meat since they are rich in amino acid content especially lysine that contributes from their high protein content. They also comprises of low total fat,

cholesterol free and excellent amount of dietary fiber. The fungus is also easy to cultivate and available in processed and fresh form. Nutraceuticals and functional foods derived from mushrooms are quite recent. In fact, due to multipurpose applications and benefits, mushrooms should be considered not only as a traditional food but also as a source of high value flavourings, efficient natural dyes, as well as a raw material for functional food, food supplement and pharmaceutical ingredients.

Cooked edible mushrooms are known to be good dietary component for diabetic and heart patients. They exhibit valuable sources of nutrients and other bioactive compounds that are suitable for functional foods. The nutrient rich edible mushroom has also been reported to be useful in reducing hypertension, hypercholesterolemia and cancer (Mallavadhani *et al.,* 2006). Previously, bakery products and meat based products have been successfully developed from oyster mushroom. Edible mushrooms generally be a routine food and are widely consumed in many countries. Edible mushrooms always consider as valuable components to take advantage of their attractive taste, aroma and nutritional values. The commercial and culinary value is depends to their organoleptic properties such as their texture and flavour, being possible to differentiate edible mushroom species on the basis of their odour or aroma (Hernandez, 2003: Kalmis, 2008).

Edible mushrooms are known as low calorie functional foods that suit to the design of healthy diet food patterns. Furthermore, the significant amounts of bioactive substances present in mushrooms such as vitamins and vitamin precursors, minerals and trace elements (Kalac, 2009; Ranogajec *et al.,* 2010). Maturity influences the nutritional compositions of vegetables similarly the umami taste of edible mushrooms.